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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : F01L 1/12, 9/04

A1

(11) International Publication Number: WO 95/16106

(43) International Publication Date: 15 June 1995 (15.06.95)

(21) International Application Number: PCT/AU94/00758

(22) International Filing Date: 7 December 1994 (07.12.94)

(30) Priority Data:

PM 2811	7 December 1993 (07.12.93)	AU
PM 7944	8 September 1994 (08.09.94)	AU
PM 8441	28 September 1994 (28.09.94)	AU

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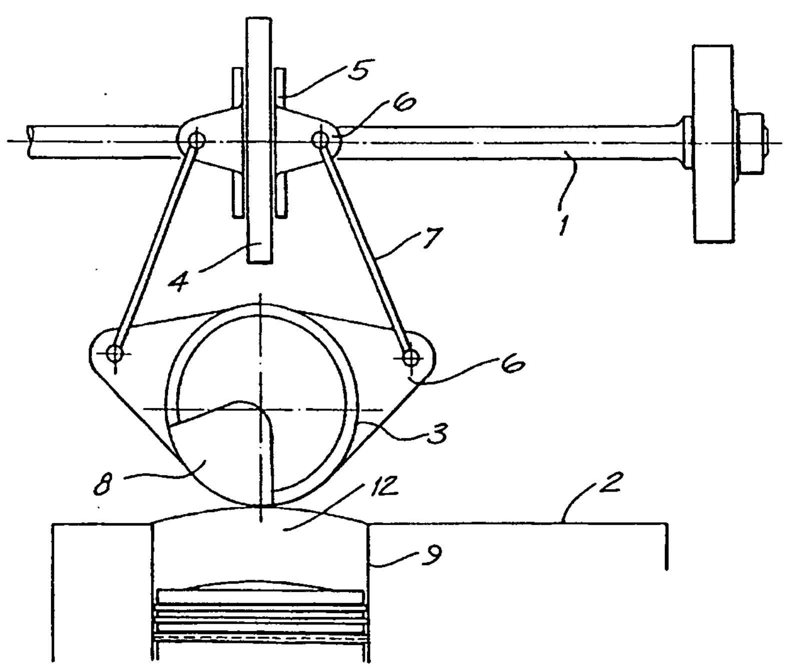
(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, TJ, TT, UA, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD, SZ).

Published

With international search report.

(54) Title: VALVE CONTROL ASSEMBLY



(57) Abstract

A valve operating mechanism for actuating an inlet or exhaust valve (3) in an internal combustion engine (2). The mechanism includes an engine driven shaft (1) to which a disc (4) is rigidly attached, and which, irrespective of the speed or position of rotation of the shaft (1), releasably couples with a valve actuator (5) to thereby actuate the valve (3). An especially preferred form of releasable coupling is by an electro-mechanical linkage between the disc (4) and actuator (5).

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VALVE CONTROL ASSEMBLY

Technical Field

The invention relates to an assembly for actuating inlet and exhaust valves of an internal combustion engine.

Background Art

It is well known that the timing of the opening and closing of inlet and exhaust valves has a major effect on the performance of engines. The proposed system employs valve timing and operation which is infinitely variable and totally controlled by the engine management system to optimise performance and efficiency under varying conditions.

Attempts have been and are being made to control the operation of automotive valves directly by electric solenoids or direct actuation by hydraulic or pneumatic means. Each method has problems to overcome. In the case of hydraulics, one problem is standing, shock or Hemholtz waves which build up at higher speeds and inhibit the speed of operation attainable. Pneumatics waste a lot of energy in compressing and releasing the hydraulic fluid, energy density is not high, and the systems are hard to silence. Both hydraulics and pneumatics also require a separate system to build and maintain pressure.

In the case of direct actuation by electric solenoids, the energy density is low, power consumption is high and dissipation of heat build-up is difficult. Speed of operation is also a problem. It is necessary to open and close each valve in around 3 milliseconds at the higher speeds of operation. With electric solenoids the magnetic flux necessary for valve actuation takes time to build up during which time a reverse electromotive force is generated which inhibits the process. Flux then has to subside and if the return movement is to be achieved by the actuating mechanism, as opposed to a spring, the polarity then has to reverse and the same build-up and decay of magnetic flux has to occur. This process brings

cylinder. It is particularly preferable in such multi-valve engines that each valve may be actuated independently of each other and independently of the speed and position of rotation of the shaft.

The ability to control the actuation of each valve independently of the other valves brings with it other possibilities including the ability to shut off the operation of certain cylinders when they are not required, thus bringing about variable displacement. Auxiliary controllable valves can be used to allow air from one cylinder to be cycled to another cylinder or chamber and vice-versa during a period of cylinder close-down, or the air can cycle in and out of the inlet valve to the inlet manifold with appropriate engine management to prevent the piston hitting a poppet valve. Alternatively, the inlet and exhaust valves can be shut and vacuums allowed to form which absorb energy on the vacuum stroke but release it on the reverse stroke. Auxiliary valves controlled by the engine management system can be used to isolate sections of the inlet manifold when cylinders are shut down. When combined with a two-stroke type exhaust port at the bottom of the cylinder and a blower mechanism for scavenging purposes the inventive assembly allows one to switch between 2 and 4 cycle at will. The same ability to switch between 2 and 4 cycle can also be achieved without two stroke type exhaust valves in the cylinders when a supercharger is fitted and used for the purpose of scavenging the cylinders through the valves. It is also possible to operate the engine using a turbocharger for scavenging purposes in a 2 cycle engine by starting the engine in the 4 cycle mode until it builds up speed and switching to 2 cycle once the turbocharger is producing sufficient boost to allow this to happen.

When combined with forced induction, it is possible to employ the cycle known as the "Miller cycle" at will. The Miller cycle relies on delayed closing of the inlet

valve after cooled compressed air is forced into the cylinder. In this case it is necessary for the engine to be fitted with a suitable supercharger but it is also possible to gain the advantages of the Miller cycle using systems described herein when the engine is fitted with a turbocharger. With total control of the valves it is possible to vary the valve timing so that a turbocharger with intercooler is allowed to spin to speeds where it develops the required pressure for the Miller cycle to become effective and then vary the timing of the inlet valve to gain the advantages of the Miller cycle.

With or without forced induction it is also possible to gain important advantages by controlling the shut-off time of the inlet valve to minimise pumping losses and gain thermodynamic advantages. The throttle can be eliminated or the use of the throttle minimised and the amount of air in the cylinder prior to the compression stroke can be controlled by the shut-off time of the inlet valve with any excess air being forced back into the inlet manifold. By this means, the cylinder is cooled and thermodynamic advantages are gained. This ability preferably requires direct-into-cylinder injection to facilitate correct air-fuel ratio. An in-cylinder pressure transducer could be used as the primary means of sensing into the engine management system to allow tighter control of air fuel ratio under differing engine regimes. The inventor of this system is co-inventor of an engine management system on which patents have been granted (see for example US Patent No. 5056026) and an in-cylinder pressure transducer on which patents are pending (see for example International Patent Application No. PCT/AU93/00359) and both of these systems are suitable for use in the system described herein.

When semi-rotary valves are used with the inventive assembly, certain other advantages can also be obtained in the placement of fuel injectors in spark ignition type

engines in that auxiliary porting can be incorporated into the inlet valve and arranged to maximise the discharge of fuel from the injector into the valve to obtain turbulence and then into the cylinder or the auxiliary port can be positioned so that the fuel spray is directly into the cylinder.

Preferably, the actuation means comprises a pair of actuator arms, each arm having a first end permanently connected to said valve and an opposite second end releasably connected to said shaft. One such actuator arm may be adapted to open the valve with the other arm adapted to close the valve. There are a number of variations of the electro-mechanical linkage for coupling the actuation means to the shaft. One such electro-mechanical linkage comprises at least one permanent magnet mounted on either the actuation means or shaft with at least one electro-magnetic mounted on the other of the actuation means or shaft, the permanent magnet and electo-magnet being movable relative to each other. Alternatively, the shaft may include a rotating disc on which either the permanent magnet or electro-magnet is mounted. Further, a gear may be used on the shaft which conveys power to another gear set at right angles to a third gear attached to each valve with the electro-magnetic coupling being attached to any of those gears. Belts or chains may also be used to convey power from the rotating shaft to the valve with an electro-magnetic coupling being interposed at one point in each drive mechanism.

One particularly preferred electo-mechanical coupling comprises a plurality of permanent magnets on the shaft or a rotating disc mounted on the shaft with electro-magnets provided on the actuation mean, e.g. actuator arms. The rotating disc will always rotate in one direction. Current may then be applied to the electro-magnets provided on the arm which will tend to

bring the electro-magnet and permanent magnet together and cause the arm to rotate in the direction of the rotating disc. An appropriate mechanical linkage extending from the arm may then extend/retract or rotate the valve. Current applied to another electro-magnet preferably on an actuator arm on the opposite side of the rotating disc, will similarly, cause that arm to couple with and rotate in the same direction as the disc to thereby apply a force to the same valve and, due to its opposite orientation to the central turning axis, extend/retract or rotate the valve in the opposite direction. Thus, each valve may be opened or closed by applying a current in sequence to electro-magnets on either side of the rotating disc. One rotating disc may provide the force, via the electro-mechanical coupling to open or close a pair of valves to service one cylinder.

Commercially available electro-magnetic rotary actuators provide several alternate means of actuation, one method being that permanent magnets are positioned radially in the adjoining disc such that when the electro-magnets are provided with electrical current, the previously stationary disc will develop a torque to rotate in the same direction as the rotating disc. Alternate means of providing a coupling effect are possible by means of arrangements of permanent magnets, the magnetism of which can be neutralised by mechanically moving the poles or which can be re-activated by the same means can be used to achieve a coupling effect between the rotating discs and the actuator arms. Alternatively, permanent magnets mounted on the discs and arms can be mechanically moved in relation to each other to achieve a coupling effect.

Commercially available actuators include electro-magnetically operated clutch and brake systems combined in one housing and it would be possible to use the brake function to hold the valve in position until movement is required.

An alternate means of actuation to convey power from the rotating disc to the actuator arms can be in the form of small clutches in which one face contains a clutch material which is made to press against one surface of the shaft or rotating disc or two pieces of clutch material which are configured in a manner similar to that used on automotive disc brakes and the two surfaces are made to engage the rotating discs from opposite sides of the disc. A combination of clutch actuation and magnetic/electro-magnetic actuation in sequence can be employed in which case the clutch mechanism can be used to start the movement of the actuator arm and the magnetic/electro-magnetic actuation can be used to hold the valve in position until it is required to reverse direction.

The force to actuate the clutch mechanisms can alternatively be generated by piezoceramic actuators which will now be described. Piezoceramic material such as lead titanate or lead zirconate are mixed with dopants and cast under conditions which achieve a crystal-lattice structure. The ceramics are heated to allow molecular mobility and then exposed to a strong electric field and polarised. The material is then quickly cooled through its Curie temperature with the voltage still applied. When a current is passed through such a material it deforms powerfully in one direction but only by small amounts. To maximise movement strips of material are bonded to both sides of flexible metal strips and the resulting movement is accentuated in the same manner as a thermostat bi-metallic strip. Depending on the physical application of the piezoceramic material to the strip and the phasing of the electric current to the material the strip can be made to bend in one direction and/or in the opposite direction at will.

The movement of a piezoceramic actuator can be multiplied by means of a lever and fulcrum arrangement if

necessary and they can be arrayed in banks and mechanically coupled when more power is required.

The advantages of piezoceramic actuators over electric solenoids or relays are more compact size, higher energy density, lower current usage, less problems with heat dissipation, higher speed of response and actuation, and precision of control.

The actuator arm of the inventive assembly may also be hinged with a limited amount of travel towards and away from the rotating disc. In this configuration, permanent magnets are disposed radially on the rotating disc and electromagnets are fitted to the actuator arms such that, depending on the direction of current flow, the electromagnets will be magnetised with polarities so as to provide either an attractive or repelling force to the permanent magnets on the rotating disc. The amount of current will be regulated to give the necessary amounts of electro-magnetism and when the force is repelling no coupling between the rotating disc and actuator arm will occur and the actuator arm will move away on its hinge from the rotating disc. When the current is reversed, an attractive force will occur, the arm will move towards the rotating disc and the resultant coupling force will tend to move the actuator arm in the direction of the movement of the rotating disc. In one configuration the permanent magnets can be disposed around the circumference of the rotating discs and the electromagnets can be arranged so that they move adjacent to the circumference of the rotating disc.

When electro-magnets are used with the present inventive assembly, there can be two or more windings on each electro-magnet, one being of heavy low resistance wire and one of lighter, higher resistance wire. Either by the provision of a set of points, or by an arrangement of circuitry, the low resistance winding can be triggered first, with an optional capacitor to provide an initial

surge of current, so that the speed of movement of the arm from rest is increased. The higher resistance coil can then be provided with current directly, or in series with the low resistance coil, to continue the movement and to provide a holding effect until the arm is de-energised prior to its return movement.

If fast-acting relays are required they can be of the piezoceramic type. Current can be induced in the rotating disc by means of a stationary adjacent coil with an invertor coming into effect at the time of starting the engine and cutting out as engine speed increases. The principles of Eddy current can be used to gain a coupling effect between the rotating discs and actuator arms in conjunction with electro-magnets mounted on the arms. An arrangement of viscous couplings under constant load but restrained by electro-magnetically operated levers or piezoceramic actuators until movement is required may also be used to provide intermittent rotary motion. Movement occurs when the restraint is removed and movement is stopped by returning the restraining lever with a shock absorbing mechanism included to minimise the effects of shock as the movement of the valve is stopped. Alternatively, the viscous coupling may be filled with an electrohelogical fluid, for example iron particles suspended in a silicone fluid, which is not viscous until supplied with a magnetic field by electro-magnetic means can be used to provide a coupling when the engine management system so dictates.

The rotating discs can be of an alternate shape so that they more resemble the rotor of an electric motor. The principles of an electrically commutated motor can be used in the coupling mechanism to minimise induction losses.

Irrespective of the means of actuation, a signal is provided from the engine management system which is used to actuate the electro-mechanical linkage through controls

or electronic amplification circuitry. This is different to other systems of variable valve timing in which the timing is set within certain limits but the timing of one or both valves can be advanced or retarded by activating servo-mechanisms. The fundamental difference is that in the inventive assembly the signal from the engine management system directly controls the opening, closing and opening dwell of the valves as well as the amount of valve opening whereas in other systems the timing is mechanically pre-set and only the advance and retard and, in certain cases, other parameters of the train of valves are altered by mechanical means through servo-mechanisms.

The engine management system can be programmed so that latency is allowed for where there are delays of response and actuation which would detrimentally affect the timing of operation.

The semi-rotary valves used with the present inventive assembly are preferably opened through approximately 90 degrees or through a variable angle as dictated by the control mechanism so that the port opening can be varied. The torque output from the electro-magnetic clutch is proportional to the current provided to the electro-magnet. A heavy clamp current can be used to ensure quick and positive actuation of the electro-magnetic coupling which can then recede to a lesser hold current.

A system of springs can be provided so that the rotation of the cylindrical valve is against the force of a spring. The torque required to rotate the valve is then proportional to the amount of rotation according to Hooke's law. The amount of rotation of the valve is therefore proportional to the applied current to the electromagnet.

A means of sensing the amount of rotation can be provided such as a rotary potentiometer or back electromotive force so that a means of indicating the

angle of rotation of the rotary valve is available to the engine management system. Piezoceramic actuators can also give a feedback as to their current position by means of current generated by movement or the movement can be controlled by modulating the electrical power supplied and the engine management system can be programmed to control the amount of valve opening by these means. The engine management system calculates the amount of rotation of the rotary valve required and when that angle is reached, the current to the clutch is reduced to hold the valve at the desired position The accuracy of this holding force is maintained through feedback from the position sensing system. Where an electro-magnetic clutch/brake is used, the brake can provide the means of holding.

A separate mechanism to control the amount of opening of the valve can be used and this typically can be a rotatable shaft placed longitudinally along the block and provided with a cam near each actuator arm such that the rotation of the shaft would alter the section of the cam against which the actuator arm will make contact at the end of its travel and will control the amount of opening of the valve. The amount of rotation of the shaft would be controlled by the engine management system by means of an actuator mechanism such as a stepper motor.

In a spring return system, the timing of opening is calculated by the engine management system and once that duration is at an end, the actuating mechanism is totally de-powered to allow the force of the springs to return the valve to its initial position.

In an alternate embodiment, the valves can be poppet valves substantially the same as standard valves now in use and the actuator arms can be made to convey force directly to the stem of the poppet valve. The rotating discs are moving in one direction only and when the actuator arms are made to move in the same direction as the rotating discs by the same means as outlined above

then movement will take place in one direction and this movement can be such that force is conveyed from the actuator arm directly to the stem of the poppet valve against a resilient means such as a spring and that resilient means will provide the force to return the poppet valve to its starting point once the force is no longer acting. Although the actuator arm is made to move in one direction the direction of movement can be reversed by connecting the actuator arm to a lever with a fulcrum placed centrally such that movement in one direction is reversed at the opposite end of the lever. One actuator arm can be used per poppet valve, or sets of valves in the case of multi-valve cylinder heads, in which case the actuator arm will act against a resilient means to provide the return action. Alternatively, two sets of actuator arms can be used per poppet valve, or set of poppet valves, with one arm providing movement in the one direction by a direct linkage to open or close the valve and the second arm to provide movement in the reverse direction through a lever and fulcrum mechanism to close or open the valve. A resilient means to help to close the valve is optional in the latter case.

Brief Description of Drawings

Figures 1A and 1B are plan and side elevational views respectively of an assembly for actuating a valve in an internal combustion engine according to a first embodiment of the present invention.

Figures 2A and 2B are plan and side elevational views respectively of an assembly for actuating a valve in an internal combustion engine according to a second embodiment of the present invention.

Figure 3 is a side elevational view of a semi-rotary valve suitable for use with the inventive assembly.

Figure 4 is a perspective view of another valve suitable for use with the inventive assembly and which can be semi-rotary or rotate with an intermittent action.

Figures 5A and 5B are side and end elevational views of an electro-mechanical linkage to releasably connect the actuation means to a rotatable shaft according to another embodiment of the present invention.

Figures 6A and 6B are side and end elevational views of an electro-mchanical linkage to releasably connect the actuation means to the rotatable shaft according to yet a further embodiment of the present invention.

Figure 7 is a side elevational view of an electro-mechanical linkage to releasably connect the actuation means to the rotatable shaft according to still a further embodiment of the present invention.

Mode(s) for Carrying Out the Invention

In Figure 1 a power take-off shaft 1 is located longitudinally to cylinder block 2 and is provided with power from the crankshaft. It is preferable to locate the shaft 1 longitudinally along the top portion of the engine 12 and to provide power from the engine by pulleys and belts, gears or chain drive. The shaft 1 is used as a power take-off and is driven at a speed which is not necessarily at half engine speed, as is the case with conventional engines fitted with cam shafts. The speed of the shaft in this invention may be more than half engine speed or multiples of the speed of the rotation of the crankshaft. A round disc 4 is attached to the power take-off shaft and spins at the same speed as that shaft. Adjacent to each face of the rotating disc is an actuator arm 5.

Round disc 4 is preferably attached to the shaft 1 near each pair of inlet and exhaust valves and rotate near adjacent actuator arms 5 which are preferably mounted on bearings on the shaft so that they can be stationary in their rest position or partially rotated to their actuated position when coupled to the shaft.

Transmission of the power from the rotating disc 4 to the valve 3 can be one way against a resilient means,

such as a spring, in which case the spring pressure is relied upon to return the valve to the closed position. In such a case only one actuator arm 5 per valve is necessary. Alternatively, it can be two way with positive return movement. In the latter actuator arms may be set on both sides of the rotating disc 4 for each pair of valves to both open and close the two valves. One can therefore see that four arms for each pair of valves are used in the case of positive return by the actuator arm, two for the inlet valve and two for the exhaust valve. Two arms are located to one side of the rotating disc and two are located on the other side of the rotating disc. In this embodiment a positive return system in which two actuator arms per valve are provided.

A semi-rotating valve, as depicted in figure 3, is located so that the port 8 in the circumference of the valve periodically opens a corresponding port in the top of the combustion chamber 12 in the cylinder 9.

In the embodiment shown the valves are semi-rotary, the valves employed are two cylindrical valves 10,11 per cylinder abutted to each other and aligned at 90 degrees or a small offset of 90 degrees in relation to the longitudinal axis of a multi-cylinder engine. The valves 10,11 are hollowed for part of their length so that one end of the inlet valve allows ingress of air or air and fuel into the valve and one end of the exhaust valve allows egress of the exhaust gases.

The open end of each inlet valve 10 is oriented towards one side of the engine and the open end of each exhaust valve 11 is oriented towards the other side. The closed end of the inlet valve 10 abuts the closed end of the exhaust valve 11 for each cylinder. A solid barrier can be interposed between the two valves or they can be separated by a small distance with optionally a lubricating film therebetween.

Towards the closed end of the valves an opening is located radially so that gases can flow through the hollow interior of the cylindrical valve body and through the opening.

The valves 10,11 are retained in housings and each housing has a port so that gases can flow through the port when the opening and the port are aligned. The general arrangement is similar to certain rotary valve systems except that the valves are two separate valves for each cylinder and can semi-rotate independently of each other.

Sealing and lubrication is accomplished in the same manner as known rotary valve technology, an example being the GV rotary valve as described in SAE paper 891793. Each valve has an individual port allowing the flow of gases to or from the cylinder when the port in the valve aligns with the port in the cylinder.

The electro-mechanical means of effecting coupling and transferring power between rotating disc 4 and actuator arms 5 is shown in more detail in figures 5 and 6. Gimballed links 7 join actuator arms 5 to the valve body 3. Fluid is depicted entering an inlet valve at 10 and exhaust gases exiting an exhaust valve at 11. The system will work irrespective of the direction speed or position of rotation of the power take-off shaft 1. When a valve is required to open, the appropriate actuator arm is coupled to the shaft 1 or rotating disc 4 by any of a number of means described herein and force is transferred which causes the actuator arm to rotate in the direction of the rotation of the shaft 1. The gimballed link 7 transfers force from actuator arm 5 to the valve body 3 and causes that valve to rotate to a position determined by the engine management system or to a stop, which can be adjustable, to thereby open the valve and align the valve with port 8. When the valve is required to close the actuator arm on the opposite side of the disc to the actuator arm previously coupled, is coupled to the shaft 1

or rotating disc 4 and power is transferred to that actuator arm causing it to rotate in the same direction of rotation of the shaft 1. Force is conveyed by a gimballed link to the opposite arm of the valve body on which force was previously exerted. This causes the valve body to rotate in the opposite direction and thereby closes the valve to a stop. At the same time the first actuator arm is returned to its rest position.

In Figure 2 a poppet valve 7 is located to provide an opening into combustion chamber 6. In this particular arrangement provision is made for positive movement to both open and close each valve (as distinct from opening against a resilient means and closing by means of the tension of the resilient means.) In this arrangement, the fulcrum 9 is depicted under the shaft and rotating discs but it can alternatively be mounted above those components. Other arrangements are also possible. It is also possible to control the amount of opening of poppet valves by similar principles as outlined above in the operation of semi-rotary valves. Gimballed links 8,12 join actuator arm 5,12 to the stem of the poppet valve 7 by means of further gimballed link 10. When the valve is required to open actuator arm 5 or 11, depending on the direction of rotation of the power transfer shaft 1, is coupled to the rotating disc 4 by any of a number of means described herein and force is transferred which causes the actuator arm 5 or 11 to rotate in the same direction of rotation as the shaft 1. To open the valve, the gimballed link 12 transfers force from an actuator arm 11 to lever arm 3 and in turn this force is applied to the stem of the valve 7 through a further gimballed link 10 causing the valve to open to a position determined by the engine management system or to a stop which can be adjustable. When the valve is required to close, actuator arm 5 is coupled to the shaft 1 or rotating disc 4 to rotate in the direction of rotation as shaft 1. Force is transferred

through gimballed link 8 to lever arm 3 and, via fulcrum 9 which reverses the direction of movement, through gimballed link 10 to valve 7 to cause the valve 7 to close.

Figure 3 depicts a semi-rotary valve 30. A port 31 for the ingress or egress of fluids is located on the circumference of the valve which has an internal passageway to the second port 32 which is located at one end of the valve and this end is located away from the centreline of the cylinder block. The other end of the valve 33 is closed and is located so that it abuts or is directly adjacent the mating valve.

The alternate semi-rotary valve design 40 depicted in Figure 4 is similar to that outlined above in respect to Figure 3 except that the flow of gases 41 go directly from a first port 42 on one side of the valve to a port 43 on an opposite side of the valve. Ports in the cylinder head provide a passage from the interior of the cylinder, on one side of each valve, to the relevant manifold, on the opposite side of the valve, with the inlet and exhaust ports aligned so that when a port is open, the flow of gas is from the port through the valve to the opposite port.

Figure 5 depicts a first embodiment of an electro-mechanical linkage to releasably couple the shaft 53 or the rotating disc 51 to actuator arm 52. Rotating disc 51 is affixed to power take-off shaft 53 and rotates at the same speed as that shaft. This embodiment relates to a positive return system and therefore two actuator arms 52 are provided for to each valve. If the system provided for a return action from pressure against a resilient means then only one actuator arm 52 would be required per valve and two of the arms to one side of the rotating disc 51 could be eliminated. The ends of each actuator arm 52 preferably have a small section bend at right angles to the main section. Each valve, as shown in Figures 1 and 2, may be connected to the actuator arms 52 by a pair of

levers or gimballed links such that the force applied to one link will tend to open the valve to a stop and a force applied to the other link will tend to close the valve to a stop. The stop may incorporate a shock absorber. A peg 57 is provided on the right angle section at the extremity of each arm to link the actuator arm 52 to the valve. The actuator arms 52 are mounted on bushings or bearings 58 and 59 which are prevented from movement by circlips 50 on the power take-off shaft 53. Solenoids 54 are mounted on each actuator arm 52 and contain an armature 61 free to move inside the solenoid 54. The solenoids 54 preferably have two windings. Winding 65 is a heavy duty low resistance high current winding which is powered directly or through a capacitor to provide an initial surge of current to facilitate a quick response and to provide the initial movement of the solenoid when the current is applied. Once the initial movement has occurred the electric current is re-directed to the higher resistance lower current winding 64 for the purpose of continuing the movement of the arm and to hold the arm in position until a return movement is required. The re-direction of the current is achieved by a set of points (not shown) which open as soon as movement occurs and prevents current from going directly to one end of the heavy duty input wires 62 and routes the current through both heavy and lighter duty coils 64 and 65. Alternatively, this re-routing process can be managed by the engine management system on a time basis or through clamp and hold drivers.

Permanent magnets 55 are located around the rotating disc 51 and positioned so that the polarity of all magnets are all in the same direction. Preferably this rotating disc 51 will be of a non-magnetic material such as aluminium. When no movement of the actuator arms 52 is required, the solenoids 54 are powered through the higher resistance coil 64 with a current the polarity of which

will magnetise armatures 61 so that the ends of the armatures closest to permanent 55 will be of the same polarity as the closest faces of the permanent magnets 55 and the armatures 61 and the permanent magnets 55 will exert a repelling magnetic force on each other to make the armatures 55 move to the position fully within the armature housing. Due to this increased separation of the permanent 55 and electro-magnets 61 and the mutually repelling force, the attractive force between the two sets of magnets is minimised and any tendency for the actuator arms 52 to be affected by a coupling force with rotating disc 51 is minimised. Accordingly, movement can be prevented by a light spring (not shown).

When movement of an actuator arm 52 is required the polarity of the current to the solenoid 54 is reversed and current directed to low resistance windings 65. The polarity of the magnetism at the end of the armature 61 closest to permanent magnets 55 is now reversed and an attractive force exists between the two sets of magnets which tends to move armature 61 towards the permanent magnets 65. The stepped shape of the armature 61 limits the amount of movement. The armature now moves to a position as has the armature 56 shown in the drawing. The two sets of magnets 56 and 55 strongly attract each other and there is a coupling such that actuator arm 52 will move in the same direction as rotating disc 51. Actuator arm 52 now moves until it is forced to stop by current limiting or by a physical stop which can be adjustable and is not shown. As soon as actuator arm 52 moves the current is re-directed so that it flows serially through both windings 64 and 65. Force is transmitted via peg 57 to a gimballed link and then to the valve which opens. When the valve is required to close the polarity of the current to the energised solenoid is reversed with current initially going to the low resistance winding 15. The polarity of the armature now again reverses so that like magnetic

poles are facing each other forcing armature 56 to move to retreat into the solenoid housing thus minimising the magnetic coupling force between the two sets of magnets. The same sequence of application of current is now applied to the solenoid located on the opposite face of the rotating disc 51 so that a coupling force is exerted between the armature of that solenoid and the rotating disc 51 and the actuator arm moves in the same direction as the rotating disc. Under Figures 1 and 2 it is described how the movement of the second arm can close the valve that was previously open. At the same time the actuator arm previously energised is returned to its original position by means shown under figures 1 and 2.

Figure 6 depicts an alternative system for transferring power from the power take-off shaft 53, by means of rotating disc 51 to actuator arms 52 through a clutch system the power for which is provided by piezoceramic actuators 70. Actuator arms 52 are located adjacent to rotating disc 51 by means of bushings 58 and 59 on the power take-off shaft 53 and are prevented from movement by circlips 60. Piezoceramic actuators 70 are located on the actuator arms so that the moveable end can exert pressure on links 72 to urge clutch 71 toward the disc 51 or shaft 53. When current of the correct polarity and phasing is applied to both pieces of piezoceramic material 75 and flexible metal arm 76, the moveable arm will bend as shown by numeral 74 and exert a strong force on links 72 which will urge the clutch (see clutch 73 in the drawing) toward to disc 51 thereby moving one face of the clutch, which consists of suitable frictional clutch material, such that it contacts one face of the rotating disc 51. A coupling force is exerted between the one face of clutch 73 and the rotating disc 51 which will cause the actuator arm 52 to rotate in the same direction of rotation as the rotating disc 51 to a position dictated by the engine management system by means

of position sensors and/or current feedback or to a physical stop (not shown) which can be adjustable. At this point the engine management system can decrease the current flowing to the piezoceramic actuator 70,74 to hold it in position until a reverse movement is required. Force from the movement of the actuator arm is transferred through peg 57 to a gimballed link which transfers force to open or close a valve as described under figures 1 and 2. When the opposite movement of the valve is required to close or open the valve, the engine management system cuts off all flow of current to the piezoceramic actuator previously energised and applies current to the piezoceramic actuator on the actuator arm located on the opposite face of the rotating disc in the same sequence causing that arm to be coupled to the rotating disc or shaft and causing that actuator arm to rotate in the same direction as the rotating disc or shaft. It is described under Figures 1 and 2 how the movement of this second arm can exert force on the valve to reverse the movement of that valve. At the same time the actuator arm previously energised is returned to its original position by means shown under Figures 1 and 2. There are four arms shown in Figure 6 however, if a resilient means was installed to provide pressure for a return movement then only one arm per valve would be necessary.

To minimise the movement of an electro-mechanical linkage such a linkage can be mounted inboard of the actuator arm close to the power take-off shaft or alternatively as shown in Figure 7 can be mounted so that it is stationary and exerts pressure onto a sliding arm attached to the actuator arm with the pressure applied through mechanical linkages to operate a clutch or to alter the position of magnets on the actuator arm to effect coupling of the actuator arm to the rotating disc. Such a solenoid can have two solenoids in the one body acting on a common shaft and the solenoids are actuated in

sequence by the engine management system to help to overcome problems of speed of operation.

In Figure 7, the rotating disk 81 is attached to power take-off shaft 83 and the actuator arm 82 is attached to the power take-off shaft 83 by bushing assembly 84. Clutch 85 can bear against rotating disc 81 when force is applied to rod 86 thereby causing actuator arm 82 to rotate in the same direction of rotation as the rotating disc 81. Flexible mounting 87 holds lever arm 88 in place. Solenoid 89 is attached by means not shown so that its housing is stationary and when actuated the rod 90 linking the solenoid's armatures can exert pressure on lever arm 88 at point 91 thereby activating the clutch. Solenoid 89 has two separate elements 93 and 92 both of which can act separately as a solenoid and are linked by common rod 90 so that the activation of either solenoids 93 and 92 will move rod 90. Solenoids 93 and 92 are actuated in sequence by the engine management system to minimise problems of speed of response of the solenoid caused by the build-up and decay of magnetic flux and back electromotive force. The solenoid's rod 90 will slide at point 91 and friction can be minimised by a ball bearing or wheel being installed at point 91.

Industrial Application

The present invention is suitable for any type of internal combustion engine and is particularly suitable for internal combustion engines which use poppet or semi-rotary valves.

CLAIMS

1. An assembly for actuating a valve in an internal combustion engine, said assembly comprising a rotatable shaft driven by the internal combustion engine and an actuation means extending between said shaft and said valve, said actuation means being releasably connected to said shaft such that irrespective of the speed or position of rotation of said shaft, said actuation means may be coupled to said shaft to actuate said valve.

2. An assembly as claimed in claim 1, wherein said actuation means is releasably connected to said shaft by an electro-mechanical linkage, such that upon activation of said linkage said actuation means is coupled to said shaft over a portion of its rotation to move between a rest position and actuated position to open or close said valve.

3. An assembly as claimed in claim 1 or 2, wherein said valve is a poppet valve, said actuation means being adapted to extend or retract said valve.

4. An assembly as claimed in claim 1 or 2, wherein said valve is a semi-rotary valve, said actuation means being adapted to rotate said valve.

5. An assembly as claimed in any one of the previous claims, wherein said actuation means comprises a pair of arms, each arm having a first portion end permanently connected to said valve and a second portion end releasably connected to said shaft.

6. An assembly as claimed in claim 5, wherein one of said arms is adapted to open said valve and another of said arms is adapted to close said valve

7. An assembly as claimed in claim 6, wherein said arms are connected to each other, such that movement of one arm from its respective rest position to its actuated position to open or close said valve also effects return of the

other arm from its respective actuated position to its rest position.

8. An assembly as claimed in any one of claims 5-7, wherein said shaft passes through said arms, such that upon activation of said electro-mechanical linkage said arms rotate with said shaft.

9. An assembly as claimed in any one of the previous claims, wherein at least one disc is mounted on said shaft, said actuation means being releasably connected by said electro-mechanical linkage to said disc.

10. An assembly as claimed in any one of the previous claims, wherein said electro-mechanical linkage comprises at least one permanent magnet mounted on one of said actuation means and said shaft or disc and at least one electro-magnet mounted on the other of said actuation means and said shaft or disc, said permanent magnet and said electro-magnet being movable relative to each other.

11. An assembly as claimed in any one of the previous claims, wherein said electro-mechanical linkage comprises at least one stationary electro-magnet mounted on the engine from which extends an elongated armature towards said actuation means, said armature being reciprocal between a first and second position to couple and uncouple respectively said actuation means to and from said shaft.

12. An assembly as claimed in claim 11, wherein said electro-mechanical linkage comprises a plurality of permanent magnets and/or electro-magnets to alter timing of the closing/opening of the valve.

13. An assembly as claimed in any one of the previous claims, wherein said electro-mechanical linkage comprises at least one piezoceramic actuator mounted on one of said actuator means and said shaft or disc.

14. An assembly as claimed in any one of claims 11-13, wherein a clutch extends between said actuation means and said disc or shaft, said clutch being urged towards said shaft or disc by said piezoceramic actuator or the movable

one of said permanent or electro-magnet to couple said actuation means to said shaft or disc.

15. An assembly as claimed in any one of the previous claims, wherein said valve is a semi-rotary valve, said actuation means including a viscous coupling to provide a constant rotary force to said valve, said valve being engaged by a lever such that a management system of the engine is adapted to engage and disengage said valve with said lever to cause intermittent rotating movement of said valve.

16. An assembly for actuating a valve in an internal combustion engine as defined in claim 15, wherein said viscous coupling is of an electrohelogical type.

17. An assembly as claimed in claims 11 and 12, wherein said electro-magnet includes a primary, heavy-duty, low resistance winding to provide fast initial movement and a secondary winding of high resistance to continue movement and provide holding power until de-energised.

18. An assembly as claimed in any one of claims 11-17, wherein said actuation means comprises a clutch means adapted to effect initial movement of the valve and a magnetic coupling means adapted to continue movement of the valve and hold the valve in the open or closed position.

19. An assembly as claimed in any one of the previous claims, wherein actuation of the valve is against a resilient means, the return movement of said valve being effected by means of pressure exerted by said resilient means.

20. An assembly as claimed in any one of the previous claims, wherein said assembly further includes sensors adapted to detect the amount of valve opening and feed a signal to the engine management system indicative of the amount of valve opening.

21. An assembly as claimed in any one of the previous claims, said assembly further including a moveable

mechanical stop or cam adapted to limit the amount of opening of the valve.

22. An assembly as claimed in any one of the previous claims, said assembly further including a programmable engine management system adapted to effect variable displacement of the internal combustion engine by ceasing valve actuation and/or fuel delivery to one or more cylinders.

23. An assembly as claimed in any one of the previous claims, said assembly further including auxiliary valves adapted to control the flow of air in the inlet manifold such that air may be cycled from one cylinder to another wherein the engine management system controls actuation of the respective inlet poppet valves in the cylinders to momentarily or partially close the inlet poppet valve when a piston approaches top dead centre to prevent the piston hitting the poppet valve.

24. An assembly for actuating a valve in an internal combustion engine substantially as hereinbefore described with reference to the accompanying drawings.

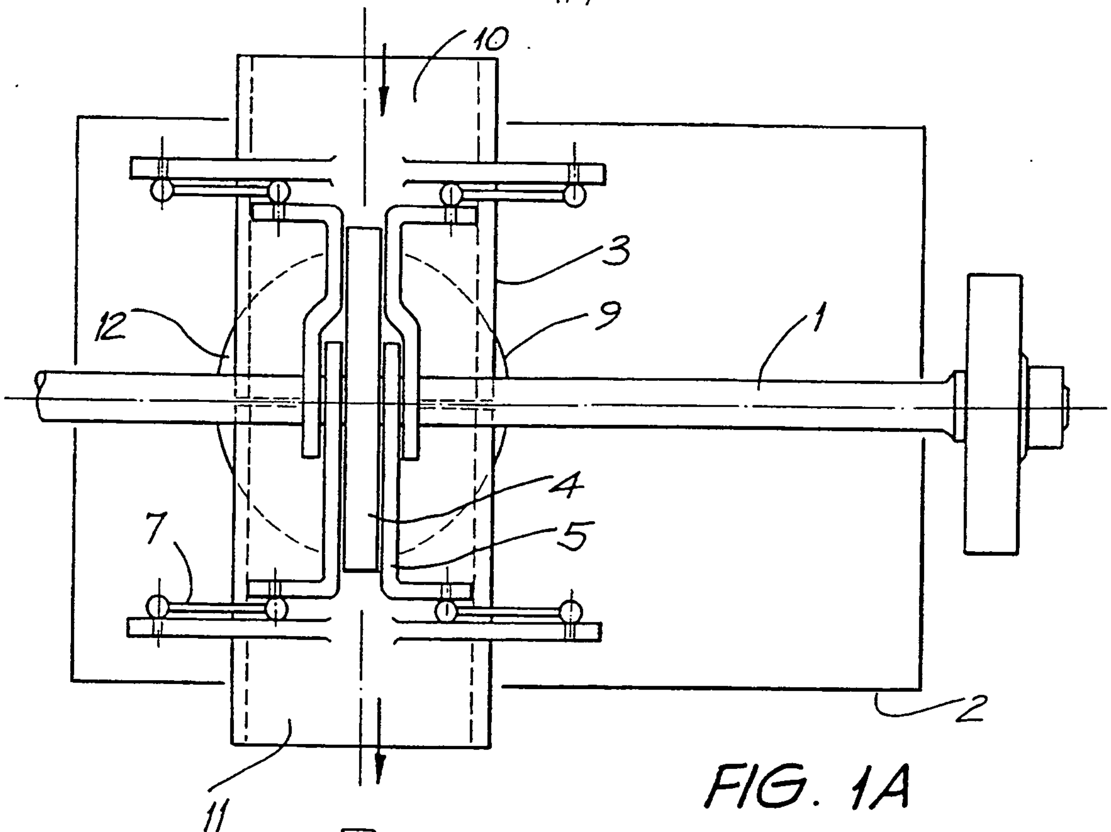

FIG. 1A

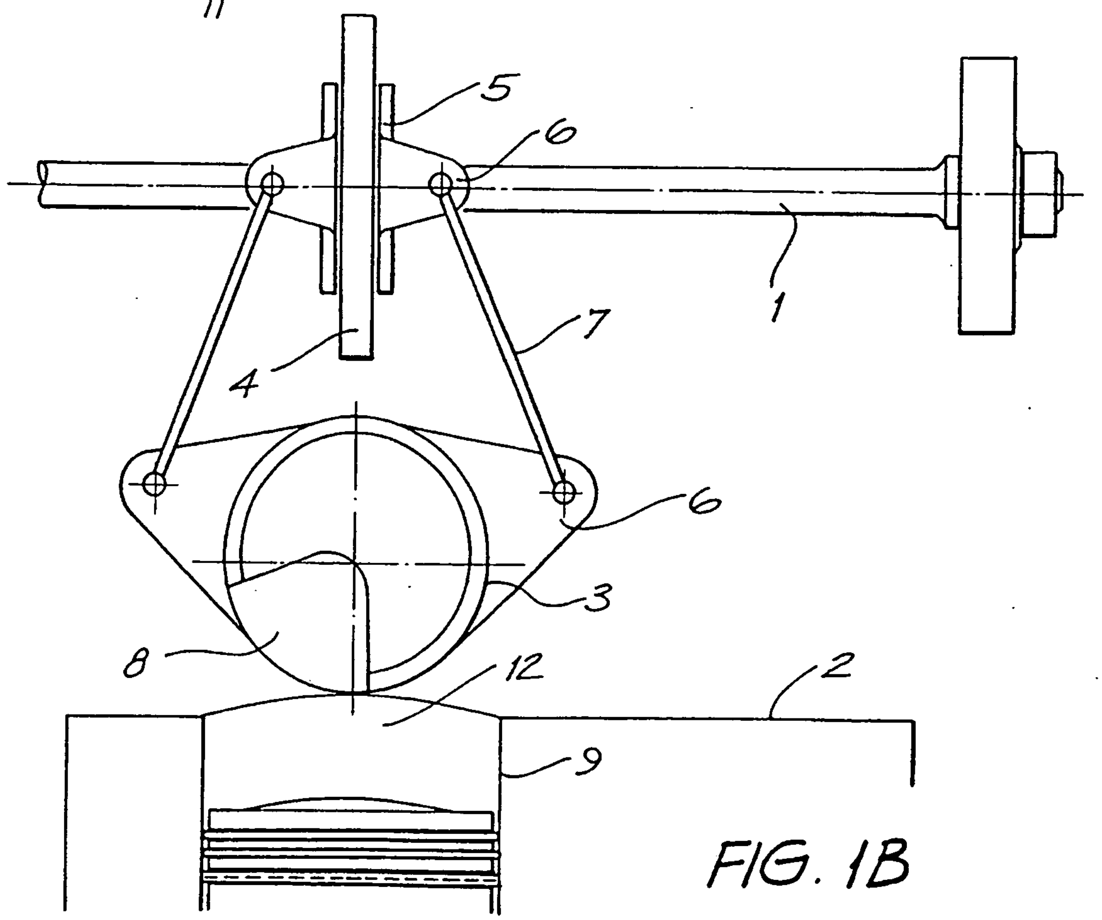

FIG. 1B

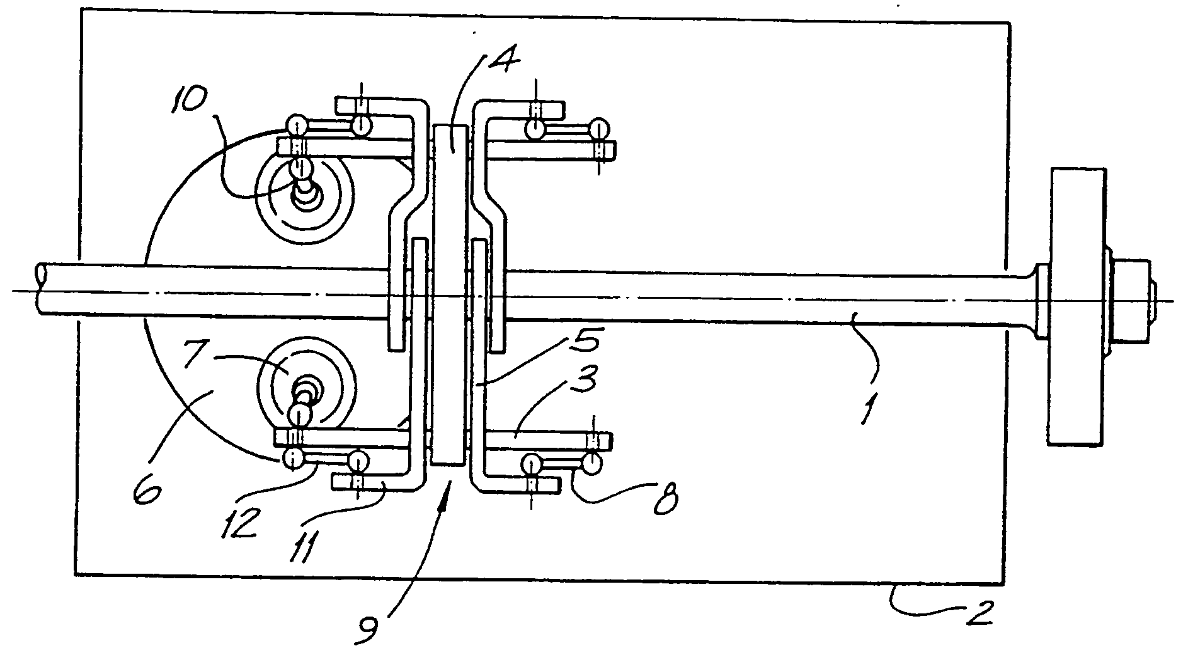

FIG. 2A

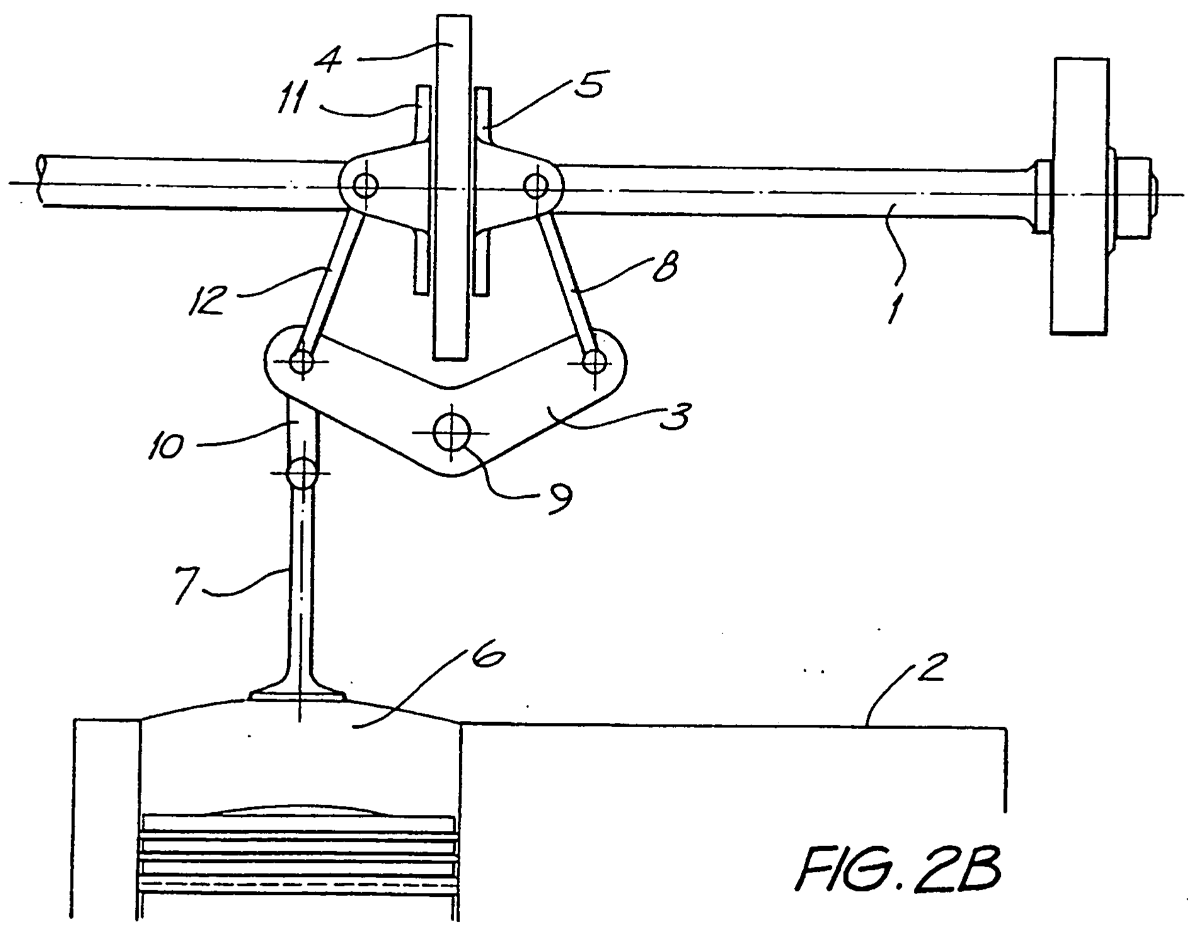

FIG. 2B

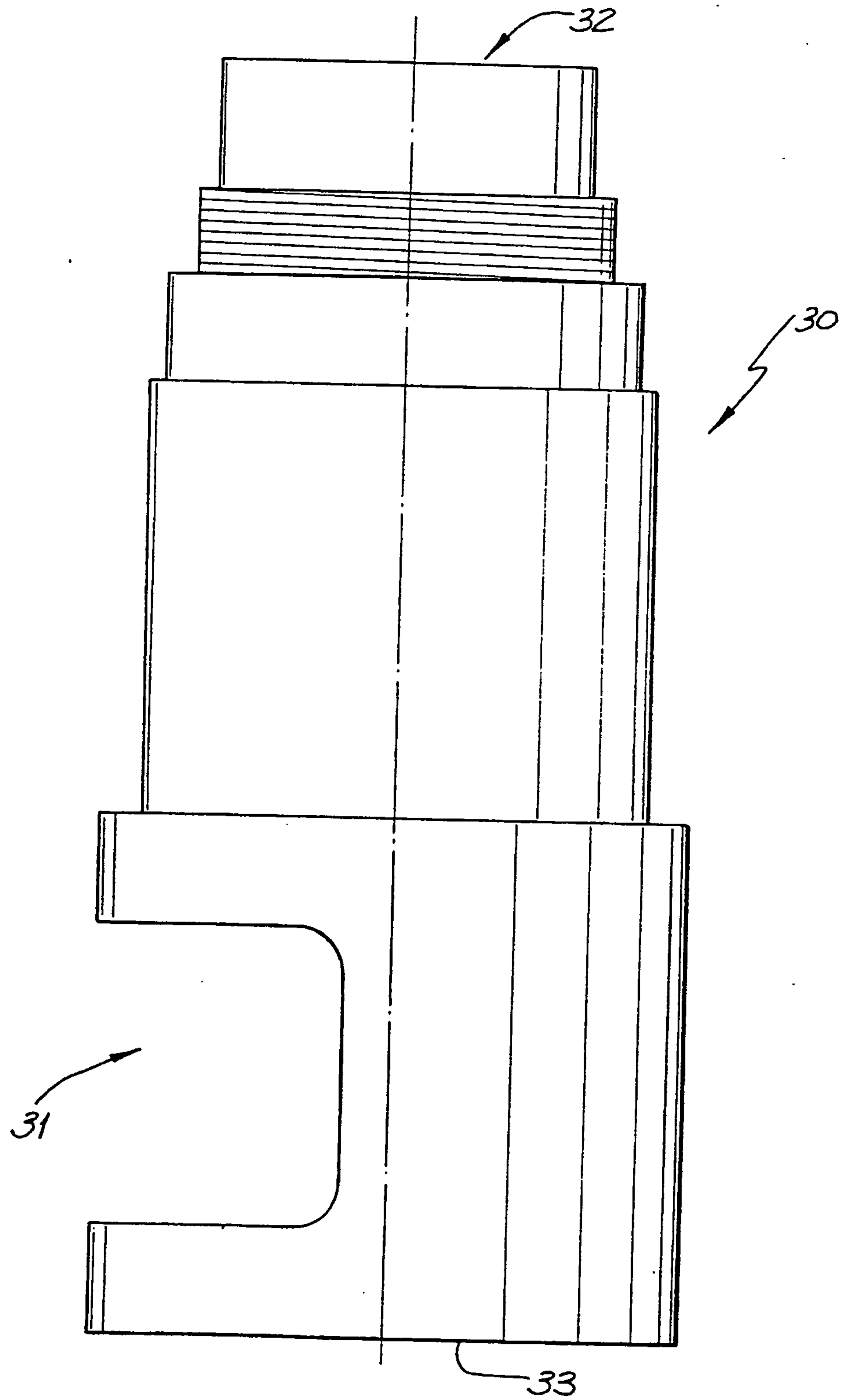

FIG. 3

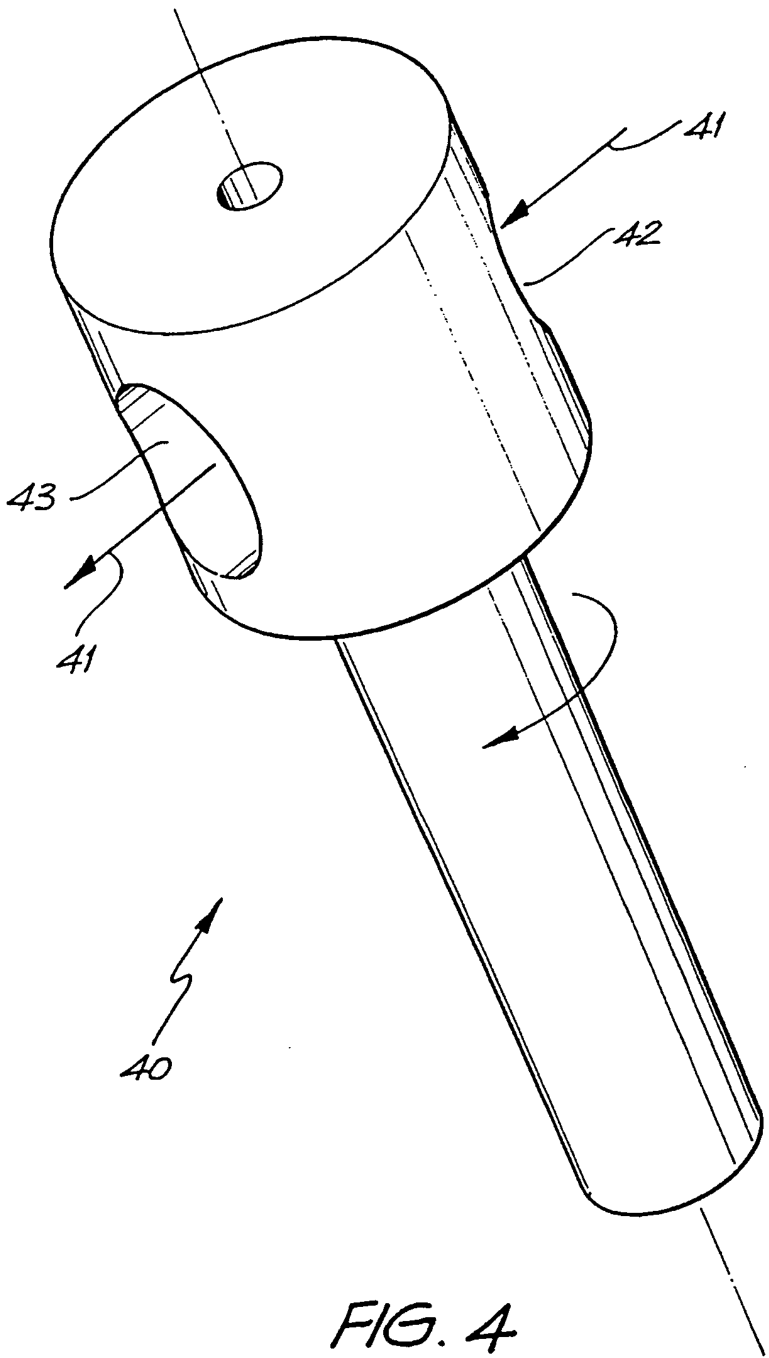

FIG. 4

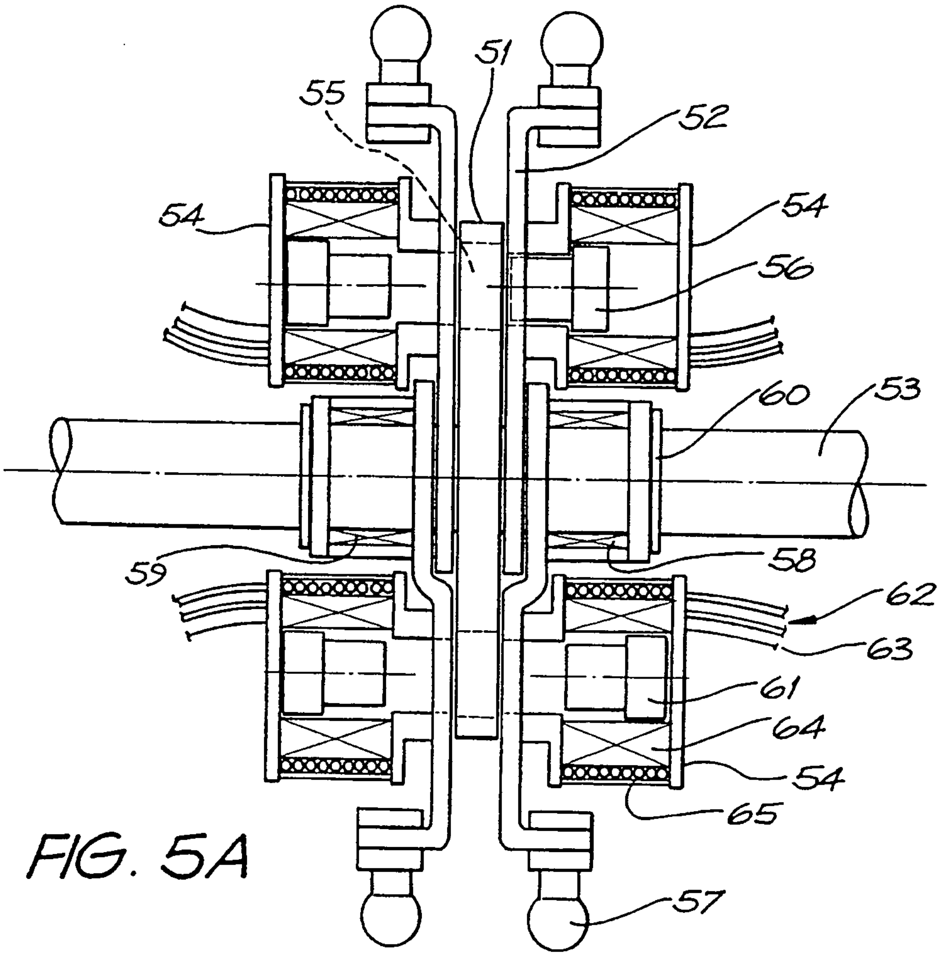
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FIG. 5A

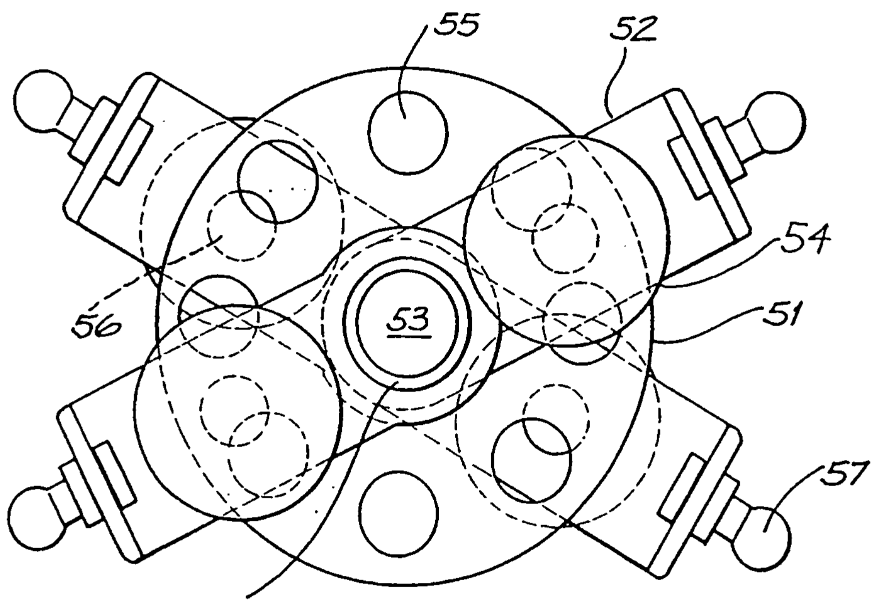
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FIG. 5B

6/7

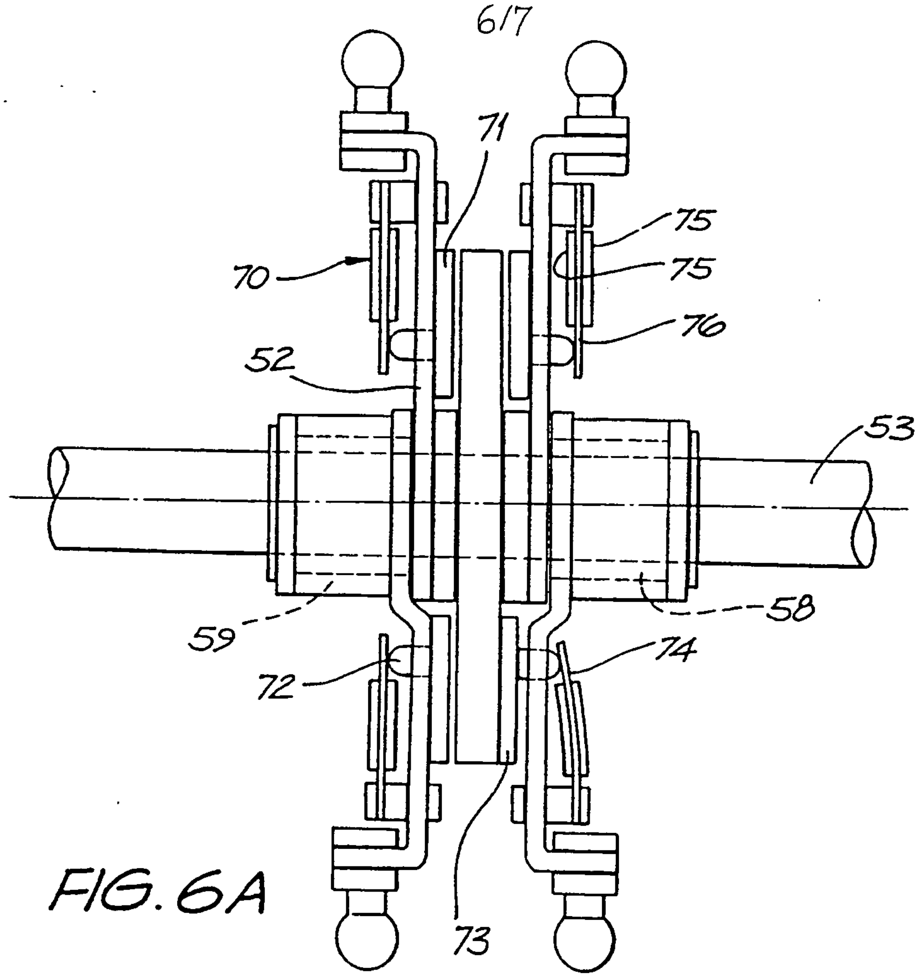

FIG. 6A

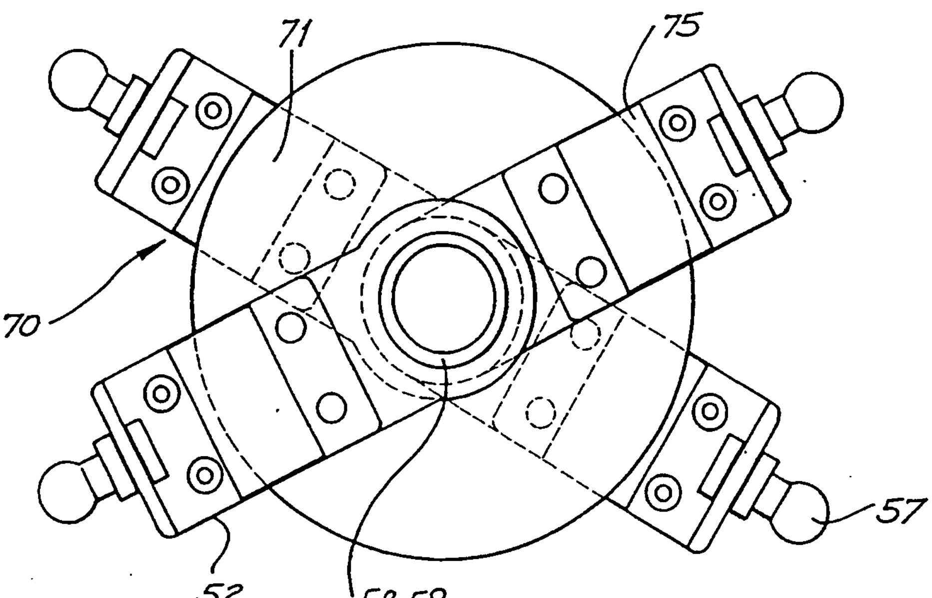

FIG. 6B

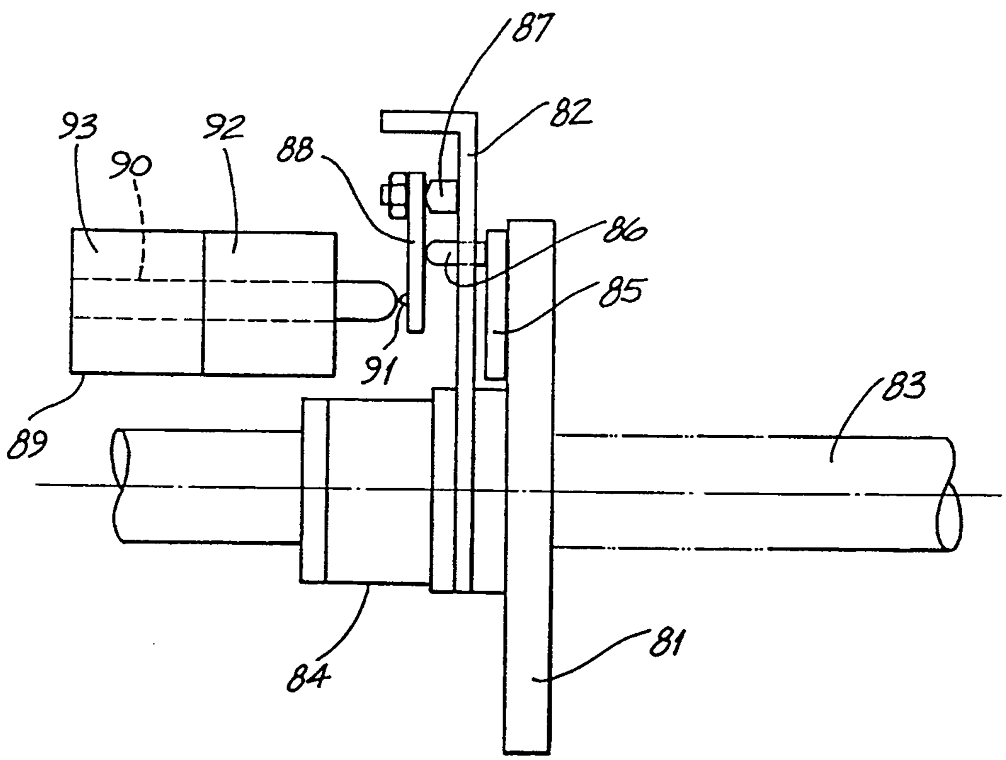

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 94/00758

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.6 F01L 1/12, 9/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC F01L 1/12, 9/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: IPC as above

Electronic data base consulted during the international search (name of data base, and where practicable, search terms used)
DERWENT

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	Patent Abstracts of Japan, M-1067, page 112, JP,A, 2-259212 (NISSAN MOTOR CO LTD) 22 October 1990 (22.10.90) abstract	1-4, 9-10
X	US,A, 4256065 (HIRT) 17 March 1981 (17.03.81) column 2, line 38-column 3, line 38	1-4, 9-10, 19

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 February 1995 (02.02.95)	17 Feb 1995 (17.2.95)

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No. 06 2853929	C.M. WYATT Telephone No. (06) 2832538

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	4256065	DE	2754624	FR	2411303	GB	2009844
		IT	1101480	JP	54086820		

END OF ANNEX